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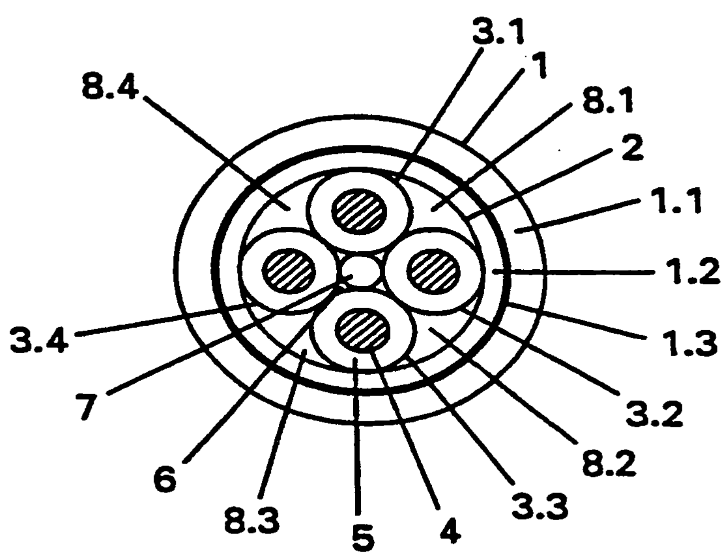
(54) Title: HYBRID TELECOMMUNICATION CABLE

(57) Abstract

A hybrid telecommunication cable comprises four electric conductors (3.1 to 3.4 inclusive) in a balanced quad-group configuration included within a cable jacket (1). In a central cavity (6) between the four electric conductors and/or in peripheral cavities (8.1 to 8.4 inclusive), there is included an optical conductor (7). The optical conductor is an optical fibre (7.1), which is partially thickened up with a fixed sheathing (7.2) up to a maximum diameter (d_3) which is smaller than a standard diameter (d_{3s}). Advantage: optical conductor may be included in the cable without increasing the diameter (d) of the cable and disturbing the balanced quad-group configuration, or facilitates the design of cables with a smaller diameter.



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Hybrid telecommunication cable.

A. BACKGROUND OF THE INVENTION

The invention lies in the field of cabling in a subscriber-connecting network. More in particular, the invention relates to a hybrid telecommunication cable comprising four electric conductors in quad-group configuration, an optical conductor, and a cable sheath which envelops the electric and optical conductors.

For cabling subscriber-connecting networks, the applicant has developed trailing cables and corresponding thin guide tubes. The guide tubes are used in bundles which run from a "curb", and the guide tubes are conducted from the bundles to the separate home connections. The bundles may be laid directly in the soil, but also in larger protecting tubes such as, e.g., those described in reference [1]. For the actual connection of a subscriber to the network, a cable is installed in the guide tube corresponding to the home connection. In such a guide tube, a copper or an optical fibre cable is installed to provide the subscriber to be connected with a copper or an optical fibre connection according to his (capacity) needs. As copper cable, there is used a so-called quad cable (two pairs of electric conductors in a quad-group configuration), at first to continue the connection options of subscribers of the current public network. In the event of future transition to an optical network, the quad cables may be replaced by optical fibre cables. Both types of cables may be provided with a metal screen for electric shielding and waterproofness, and with an enveloping jacket. The dimensions of the cables, and of the guide tubes in which the cables must be installed, are strictly adjusted to one another. In this connection, the inner diameter (in this case, 5.5 mm) of the guide tube used and the outer diameter (in this case, 4.5 mm) of particularly the quad cable, on the one hand was chosen as small as possible, mainly on account of cost considerations, while on the other hand there was still obtained a sufficient degree of protection and feasibility of installing the cables in the guide tubes. In this connection, the quality and the mutual position of the cores and of the group within the metal screen are balanced in such a manner that the signal attenuation and cross talk remain within limits imposed. The option of offering, by way of the guide tube in question, both a quad connection and an optical fibre connection to a home connection, however, is not available. That is why there is a need of a hybrid telecommunication cable which,

apart from the four copper cores, also comprises at least one optical fibre in such a manner, however, that the outer diameter of the hybrid telecommunication cable is not, at any rate not substantially, larger than that of the said quad cable. Hybrid cables per se are known, in a connecting network, to provide home connections with a quad connection and/or an optical fibre connection. Thus, in reference [2] there is described a cable, inter alia, whose base bundle consists of one or more copper quads in addition to a bundle of optical fibre cores in a loose or fixed envelope. Of the latter, the outer diameter of course is much too large. It is customary to join glass fibres, provided with a standard primary coating (typical diameter: 250 μm), in tubes ("loose tubes") or in grooves ("slotted cores") to form a cable. In order to prevent signal attenuation as a result of "microbending", the fibres therein must lie as freely as possible. For a singular standard glass-fibre, this requires at least an inner diameter of approx. 1 mm for the "loose tube", while a groove requires at least the same minimum diameter. A standard glass-fibre core having a fixed sheathing ("tight buffer" or "tight jacket"), on which an additional sheathing ("buffer" or "jacket") having a standard diameter of 900 μm has been applied directly on top of the standard coating as protection against "microbending", as described in, e.g., reference [3], is too thick as well.

Neither will the use of an already commercially available plastic optical fibre (POF) of the Step Index type (SI-POF) be able to offer a solution here. According to design specifications of the ATM Forum for a standard POF link [ATM = Asynchronous Transfer Mode], as enumerated, e.g., in Table 3 of Reference [6], a standard SI-POF has a typical sheathing diameter of 1000 μm (min./max. 950/1050) and a fixed sheathing ("tight jacket") having a typical diameter of 2.2 mm (min./max. 2.0/2.4). A Graded Index POF (GI-POF) having a smaller sheathing diameter (typically about 500 μm) still is in the laboratory stage. For this type of POF, there may be expected a typical standard diameter of approx. 1 mm.

Reference [4] describes several variants for a hybrid telecommunication cable wherein electric conductors are used which, within the cable core, are mutually insulated from one another by the dielectric properties of the optical conductors lying in between. A hybrid cable of the type referred to above is known therefrom. The

optical conductors are standard optical fibres ("loose-tube" or "tight-buffer"). To realise a balanced copper/quad cable with said known technique, i.e., with a quad group of electric conductors, there are required at least four standard optical fibres, also in a quad-group configuration, the electric conductors being included, as thin bare-metal wires, outside the quad group of the optical fibres in gaps between the optical fibres and the enveloping cable jacket. As a result, the electric conductors come to lie proportionally too far outwards with respect to a metal screen which is included in the cable jacket. The desired cross-talk and attenuation properties of the quad group of electric conductors then requires a larger diameter for the metal screen and, as a result, for the entire cable.

B. SUMMARY OF THE INVENTION

The object of the invention is to provide for a hybrid telecommunication cable which meets the above need. In addition, a more general object of the invention is to offer the option of realising hybrid telecommunication cables of the type referred to above for relatively short distances having a more restricted diameter than is possible with standard optical fibres. To this end, a hybrid telecommunication cable of the type referred to above according to the invention is characterised as in claim 1. As a result, the outer diameter of the insulated electric conductors may remain limited. To this end, a preferred embodiment of the cable according to the invention is characterised as in claim 2. This means that in a hybrid cable according to the invention there is used an optical fibre which is not, or only to an insufficient extent, provided with a fixed protective sheathing. In such a cable, the optical fibre therefore does not meet a standard requirement for protection, such as against all sorts of external influences and against "microbending" having a greater signal attenuation as a result. Still, it may make sense to include such an optical fibre in the cable, since on the one hand the cable sheathing may offer sufficient protection against external influences, while on the other hand, in the event of using such cables on relatively short distances, as is the case when cabling in buildings or in the last stage of a subscriber connecting network, where the cable length in most cases remains limited to approx. 200 m, signal attenuation as a result of possibly occurring "microbending"

will remain within permissible limits. For standard glass fibres this means that these are provided with a standard primary coating, but that they are not, or only to a limited thickness, provided with a secondary coating, and therefore not "thickened up" to the standard thickness of 900 μm or provided with the usual "loose tube" and the like. For plastic optical fibres (POF) this means that a customary fixed sheathing is not, or only to a limited extent, available up to a thickness smaller than a relevant standard thickness, and therefore for an SI-POF up to a thickness which is smaller than corresponds to the minimum standard diameter of 2.0 mm.

Other preferred embodiments have been summarised in the remaining subclaims.

Reference [5] discloses an energy cable having a number of mutually insulated electric conductors having equal, circular-sector-shaped cross sections, enveloped by a cable sheath, one or more optical conductors having been included in the remaining space between the conductors within the cable sheath. A dimensioning problem relating to the optical conductors to be included within the cable sheath, however, is not under discussion. Neither does the inclusion need to take into account a possible disturbance of electrical properties of the electric conductors.

C. <u>REFERENCES</u>

[1] W. Griffioen, et al., "A new, extremely versatile, access network cabling concept for migration to optical fiber", Proc. 45th IWCS (1996), pp. 485-489;

[2] DE-A-4138374;

[3] S.-T. Shiue, et al., "Axial strain induced microbending losses in tightly-jacketed double-coated optical fibers", J. Opt. Commun., 18 (1997) 1, pp. 10-14;

[4] DE-A-4416545;

[5] DE-A-19544898;

[6] J. Krauser en O. Ziemann, "Polymer optical fibres for in-house cabling", Eurescom Workshop ANCIT, Turin (IT), 30-31 maart 1998, pp. 1-9.

The references are considered as being incorporated in the present application.

D. BRIEF DESCRIPTION OF THE DRAWING

The invention will be explained in greater detail by reference to a drawing comprising the following figures:

FIG. 1 schematically shows, in cross section, a first embodiment of the hybrid cable according to the invention;

FIG. 2 schematically shows, in cross section, a variant of the first embodiment according to FIG. 1;

FIG. 3 schematically shows, in cross section, a second embodiment of the hybrid cable according to the invention;

FIG. 4 schematically shows, in cross section, a variant of the second embodiment according to FIG. 3.

E. DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 1 schematically shows, in part (a), a cross section of a hybrid cable and, in part (b), the same cross section in which the diameters of the various cable parts are designated. The cable comprises a jacket 1 and a cable core 2. The jacket consists of an outer jacket 1.1 and an inner jacket 1.2 having therebetween a metal water shield 1.3. The water shield is made of, e.g., Al film, while the inner jacket is formed by a layer of, e.g., polyester and the outer jacket of HDPE (high-density polyethylene). An inner jacket may be left out, if so desired. The cable core 2 includes four electric conductors 3.1 to 3.4 inclusive in a quad-group configuration, hereinafter also referred to as quad group 3. Each electric conductor comprises a copper core 4, surrounded by a PE-foam skin 5. Said foam skins not only serve as protection and electric insulation, but also as spacers between the electric conductors within the cable jacket. The cable jacket fits tightly around the quad group, in such a manner that the cable core has a substantially circular cross section. A central cavity 6 between the electric conductors houses an optical conductor 7 whose cross section is shown in part (c) of FIG. 1.

Assuming circular cross sections for the cable core 2, the electric cores 3.1 to 3.4 inclusive, and the optical conductor 7, as well as a given diameter d_2 for the electric conductors, there follows a diameter d_1 for the cable core 2 having a minimum value which is given by:

$$d_1 = (\sqrt{2} + 1).d_2, \quad (1)$$

and a diameter d_3 for the optical conductor 7 having a maximum value which is given by:

$$d_3 = (\sqrt{2} - 1).d_2 \quad (2)$$

Formulated differently, an optical conductor 7 having a diameter d_3 exactly fits in the central cavity 6 of four electric conductors 3.1 to 3.4 inclusive having equal circular cross sections whose diameter d_2 is a factor $(1 + \sqrt{2})$ greater than the diameter d_3 of the optical conductor.

In the optical conductor 7, there may be used both an optical glass fibre and a plastic optical fibre (POF).

The optical conductor 7 is an optical fibre 7.1 which is provided with a (possibly additional) fixed sheathing 7.2, in a similar manner and having similar material as that of a "tight-buffer" or "tight-jacket" of a standard optical fibre, but having a diameter d_3 which is smaller than a standard diameter d_{3s}. The diameter of a "bare" optical fibre 7.1 is designated by d_4. If the optical fibre 7.1 is a "bare" glass fibre (core, sheathing and primary coating having a standard diameter of 250 μm), then this is to say that the optical conductor 7 is a glass fibre which is not fully "thickened up" to the standard diameter $d_{3s} = 900$ μm which is valid for sufficient protection against "microbending". Although this means that, in use in the glass fibre, there will occur a much greater signal attenuation than in the event of the usual standard glass fibres ("loose-tube", "tight-jacket" etc.), but that for application in optical connections over limited distances which are not much greater than, e.g., approx. 200 m, such is permissible. If the optical fibre 7.1 is a plastic optical fibre of the "step index" type (SI-POF) (core and sheathing), then this is to say that the optical conductor 7 is a POF which is not fully thickened up to a minimum standard diameter $d_{3s} = 2.0$ mm valid for an SI-POF.

By providing optical fibres with such only partly "thickened up" sheathing, it is possible either to add an optical conductor to an already designed copper quad cable without increasing the diameter of the cable, or to realise new copper quad cables having a smaller

outer diameter.

Example:

In a balanced copper quad cable, in which
the diameter of the cable: $d = 4.2$ mm,
the diameter of the cable core: $d_1 = 2.52$ mm, and
the diameter of the electric conductors: $d_2 = 1.04$ mm,
a partly thickened optical fibre having a maximum diameter d_3^_=^_0.43 mm fits in the central cavity 6, without it being necessary to increase the diameters of the cable core and of the cable.

In peripheral cavities 8.1, 8.2, 8.3 and 8.4 between the electric conductors and inner jacket 1.2, there also fit such partly thickened fibres 9.1, 9.2, 9.3 and 9.4, respectively, having exactly the same maximum diameter d_3. FIG. 2 shows a cross section thereof.

In the cross section of the central cavity 6 there fit, instead of a circle having a maximum diameter $d_3 = (\sqrt{2} - 1).d_2$ (see formula (2) above), two identical circles having a maximum diameter $d_4 =$ $^1/_4^{_}d_2$. This means that, in a quad cable having the dimensions of the example referred to above, in which $d_2 \geq 1.0$ mm, in the cavity 6 instead of one partially thickened fibre, there may be included two "bare" standard optical fibres 7.1 (and therefore without the additional fixed sheathing 7.2) having a diameter d_4. This is also possible in the peripheral cavities 8.1 to 8.4 inclusive. FIG. 3 and FIG. 4, respectively, show a cross section thereof. There are designated "bare" optical fibres 10 and 11 in the central cavity 6 (FIG. 3) and "bare" optical fibres 10.1 and 11.1 in the peripheral cavity 8.1 (FIG. 4).

The balanced quad cable of the example was stranded with a pitch $P = 150$ mm and a winding radius $R_w = 1.045$ mm. The same applies to the optical fibres included in the peripheral cavities. In this connection, the fibres in the helix have a bending radius R_b which is given by:

$$R_b = R_w + P^2.(4\pi^2 R_w)^{-1} = 546 \text{ mm}.$$

This is substantially larger than the minimum permissible bending radius for standard optical fibres.

The bare copper cores 4 have a diameter $d_5 = 0.5$ mm.

Instead of an application for installation in thin guide tubes, there are also possible applications in which one or more of the hybrid cables described are stranded together to form thicker cables.

In general, it may be stated that, depending on the application and a signal attenuation permissible therein, the diameter d_3 for an optical fibre may be chosen between a minimum diameter d_4, which is required for optical conduction, and a standard diameter d_{3s}, which is defined for sufficient protection against "microbending".

Therefore:

$$d_4 \leq d_3 < d_{3s} \qquad (3)$$

having as its limits for the diameter of the electric conductors 3.1 to 3.4 inclusive:

$$(\sqrt{2} + 1).d_4 \leq d_2 < (\sqrt{2} + 1).d_{3s} \qquad (4)$$

and for the diameter of the cable core 2:

$$(\sqrt{2} + 1)^2.d_4 \leq d_1 < (\sqrt{2} + 1)^2.d_{3s} \qquad (5)$$

For a standard glass fibre having a diameter $d_{3s} = 900\ \mu m$, this means that the diameter d_1 of the cable core must be at least equal to approx. 4.75 mm. For a standard plastic optical fibre (POF) of the stepped index type (SI-POF), as it is specified in reference [6], and for which there has been specified a minimum diameter $d_{3s} = 2.0$ mm, this means that the diameter d_1 of the cable core must be at least equal to approx. 11.65 mm. For a POF of the Graded Index type (GI-POF) having an estimated standard diameter d_{3s} = approx. 1 mm, the diameter d_1 would still have to be greater than approx. 5.82 mm. By using only partly thickened-up fibres having a diameter d_3 which satisfies the inequality (3), there is possible a substantially smaller diameter for the cable core, and as a result for the entire cable.

F. CLAIMS

1. Hybrid telecommunication cable comprising

- four electric conductors included in a quad-group configuration,
- an optical conductor, and
- a cable jacket enveloping the electric and optical conductors,

characterised in that the electric conductors have substantially equal circular cross sections which touch one another in pairs and whose centres, at any rate approximately, form a square, and that the optical conductor is included in one of the spaces between the electric conductors and the cable jacket, the optical conductor being provided with a fixed protective sheathing having a diameter which is smaller than a standard diameter in force for the optical conductor in question.

2. Hybrid telecommunication cable according to claim 1, characterised in that the four electric conductors possess cross sections having a maximum outer diameter which is smaller than a factor $(1 + \sqrt{2})$ times said standard diameter.

3. Hybrid telecommunication cable according to claim 1 or 2, characterised in that the optical conductor is a glass fibre provided with a fixed protective sheathing having a maximum outer diameter which is smaller than an outer diameter in force for a secondary coating of a standard glass fibre.

4. Hybrid telecommunication cable according to claim 1 or 2, characterised in that the optical conductor is a plastic optical fibre provided with a fixed protective sheathing having a maximum outer diameter which is smaller than an outer diameter in force for a coating of a standard plastic optical fibre.

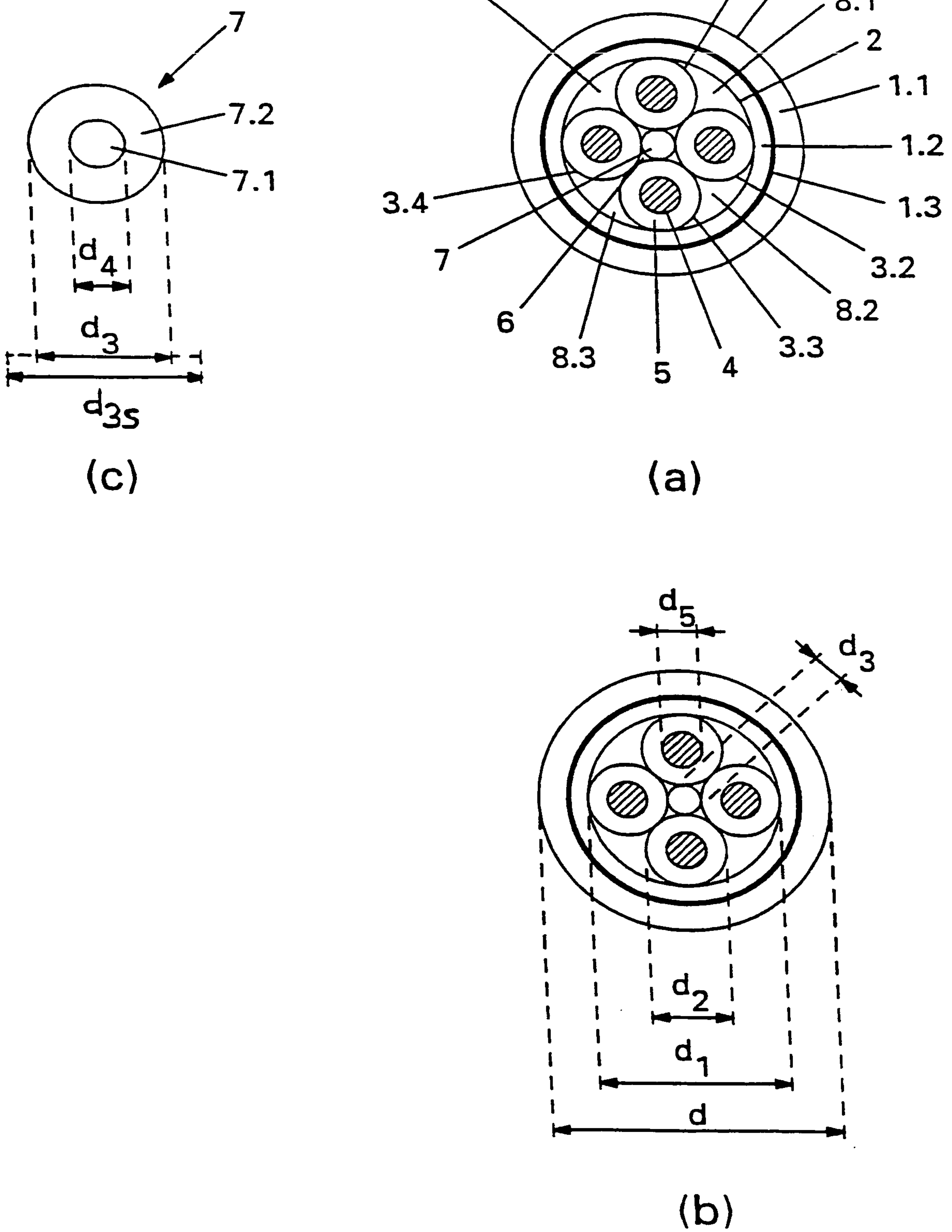
5. Hybrid telecommunication cable according to claim 1, 2, 3 or 4, characterised in that the space enclosed by the cable sheathing has a substantially circular cross section, that the cable contains at most five optical conductors which are included, each individually, in one of the spaces recessed between the individual electric conductors and between the electric conductors and the cable sheathing in an order

which is symmetrical with respect to a central cable axis.

6. Hybrid telecommunication cable according to claim 1, 2, 3 or 4, characterised in that the cable comprises a pair of optical conductors, which pair is included in the recessed space lying centrally between the four electric conductors.

7. Hybrid telecommunication cable according to claim 1, 2, 3 or 4, characterised in that the space enclosed by the cable sheathing has a substantially circular cross section, that the cable comprises at most five pairs of optical conductors, which pairs of optical conductors are included, per individual pair, in one of the spaces recessed between the individual electric conductors and between the electric conductors and the cable sheathing, in a symmetrical order with respect to a central axis of the cable.

8. Composite cable in which one or more hybrid telecommunication cables according to one or more of the claims 1-6 are stranded together with other cable elements within an enveloping cable jacket.


7
7.2
7.1
d_4
d_3
d_{3s}
(c)
3.1
1
8.4
8.1
2
1.1
1.2
1.3
3.4
7
3.2
6
8.2
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5
4
3.3
(a)
d_5
d_3
d_2
d_1
d
(b)

FIG. 1

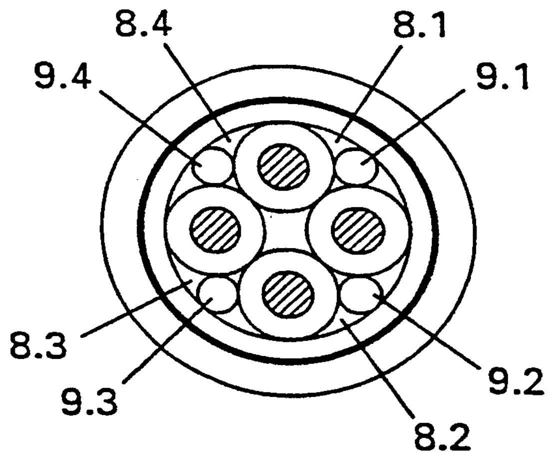

FIG. 2

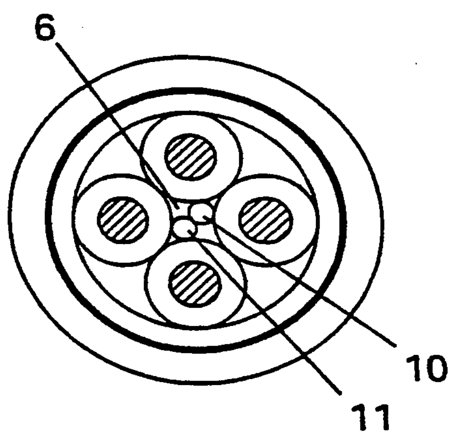

FIG. 3

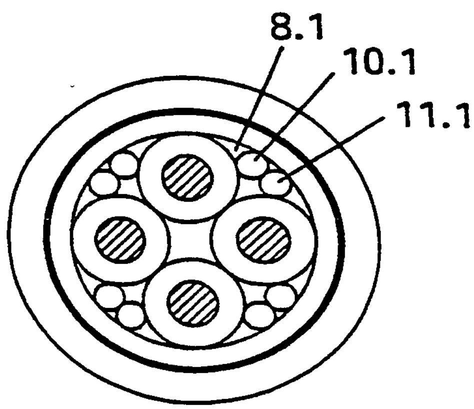

FIG. 4

INTERNATIONAL SEARCH REPORT

Int ...tional Application No
PCT/NL 98/00294

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01B11/22 G02B6/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
A	DE 32 26 265 A (MERTEN GMBH & CO KG GEB) 19 January 1984 see claims; figures ---	1
X	DE 195 44 898 A (BAYERISCHE KABELWERKE AG) 11 July 1996	1,5
A	see claims; figures ---	7
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DE 4416545 A	16-11-1995	NONE	

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